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AIR QUALITY FORT FRANCES

Annual Report, 1979

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AIR QUALITY

FORT FRANCES

Annual Report, 1979

TECHNICAL SUPPORT SECTION
NORTHWESTERN REGION
ONTARIO MINISTRY OF THE ENVIRONMENT

September, 1980

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SUMMARY

The Ministry's air quality assessment programme in Fort Frances continued in 1979 with a number of studies begun several years earlier, including vegetation assessment and air quality monitoring.

In the 1979 growing season, vegetation injury caused by airborne emissions from a local kraft pulp mill extended over 6.6 hectares, the smallest area affected since pulp production began in 1971. Most of the moderate to severe injury was restricted to a company-owned buffer zone to the north and east of the mill.

Fallout of particulate matter (dustfall) continued to exceed Ontario regulations at sites near the kraft mill. Major components of dustfall included wood fines and compounds containing high levels of calcium, sodium and sulphate. Under the provisions of a recently issued control order, the discharge of these contaminants is to meet Ministry regulations by late 1983. In late 1979, there was already evidence of reduced sodium and sulphate fallout, following the first stage of improvements in some of the mill's pollution control equipment. Particulate fallout near the Fort Frances mill is not considered hazardous to health, but is a severe local nuisance problem.

Although high concentrations of offensive odours, measured as total reduced sulphur (TRS), persisted in the vicinity of the Fort Frances mill, there was some evidence of improvement over 1978. Both the number of excursions of TRS above the Ontario guideline and the annual average TRS concentration were lower in 1979 than in 1978. At the highest levels recorded, TRS in Fort Frances might cause temporary discomfort to some individuals. Significant odour emission abatement measures have recently been commissioned at the mill. The control order specifies that all sources of TRS must comply with Ministry regulations by the end of 1982.

INTRODUCTION

The Ontario Ministry of the Environment began air quality studies in Fort Frances in 1972 to assess the effects of atmospheric emissions from a local bleached kraft pulp mill which commenced production in late 1971.

Investigations up to 1978 (1) showed that airborne contaminants from the mill often resulted in excessive fallout of particulate matter, high concentrations of malodorous gases, vegetation damage, and numerous complaints from nearby residents. The mill owners paid compensation in settlement of claims of vegetation damage and, over a period of several years, purchased a number of residences along the north and east perimeters of their property to establish a "buffer zone" of approximately 2.9 ha (hectares) between the mill and the surrounding residential-commercial area. Further benefits followed from improvements in the operation of mill process equipment to reduce the frequency and severity of releases of injurious contaminants.

The Ministry's 1979 air quality assessment programme in Fort Frances continued the studies conducted in preceeding years, including vegetation assessment and air quality monitoring.

VEGETATION ASSESSMENT

VEGETATION INJURY

Vegetation development in the Fort Frances-International Falls area was slow at the beginning of the 1979 growing season because of cold spring temperatures. No air pollution injury symptoms, or significant insect or disease damage, was noted in early June. The annual air pollution injury mapping, conducted

on August 13, showed that the 1979 "injury zone" was about 6.6 ha (Figure 1), compared with 9 ha in 1978 and 12 ha in 1977. Nearly half the vegetation damage was in the buffer zone near the mill. Injury severity was also less in 1979 than in 1978. In addition to Manitoba maple (Acer negundo), other commonly occurring trees and shrubs near the Fort Frances mill also showed signs of damage. Crowns of some trees in this area have been progressively killed back in the years since mill operations began. Two attempted plantings of trees in the buffer zone have also failed. Outside the injury zone plotted in Figure 1, no air pollution effects on vegetation were observed. Insect and disease problems were less evident in 1979 than in 1978.

There was circumstantial evidence of chlorine damage to vegetation near the mill in early September. Injury symptoms on foliage of trees and shrubs (mainly in the buffer zone), meteorological data, and information from a local witness indicate that emissions from the mill on September 1 were probably responsible for the damage. Injury would have been much greater had the fumigation occurred earlier in the growing season.

CHEMICAL ANALYSIS

Triplicate samples of Manitoba maple foliage were collected from 25 sites in the study area (Figure 2) and from two control locations approximately 4 km (kilometres) from the two kraft pulp mills (the Fort Frances mill and the parent corporation's plant 0.7 km west in International Falls, Minnesota). Sampling, sample processing and analytical methods are described in earlier reports (1, 2). Sodium determinations were made in the Ministry's Thunder Bay laboratory and chloride analyses were carried out at the Ministry's central laboratory in Rexdale.

In 1979, sodium concentrations in Manitoba maple foliage were significantly elevated only near the Fort Frances mill, mainly in the buffer zone. Comparable values for other years are

given in Table 1. The same table shows that foliar concentrations of chloride were also significantly elevated around the Fort Frances mill. The maximum values for both chloride and sodium were higher in 1979 than in 1978, possibly because of higher emissions of these contaminants in 1979 than the preceding year.

AIR QUALITY MONITORING

PARTICULATE POLLUTANTS

Dustfall

Dustfall, comprising particulate matter which settles out from the atmosphere by gravity, has been monitored at several Fort Frances locations (Figure 3) since 1972. The measurement method is described in more detail in earlier reports. All samples in 1979 were submitted to the Ministry's Thunder Bay laboratory for determination of total dustfall, pH of dustfall solutions, and soluble calcium, sodium and sulphate.

Total dustfall (Table 2) frequently exceeded the monthly and annual air quality objectives, particularly at sites nearest the Fort Frances mill. The highest levels of dustfall were nearly four times the maximum acceptable limit. Figure 4 shows that dustfall declined as distance from the mill increased. The same figure shows that sodium and sulphate, expressed as saltcake, accounted for a significant part of total dustfall. Total dustfall, sodium in dustfall (Table 4), and sulphate in dustfall (Table 5) all declined sharply after August at sites near the mill, following the first phase of reconstruction of the mill's recovery furnace precipitator. Calcium in dustfall (Table 3) was also well above background levels near the mill. At the monitoring station closest to the kraft mill (station 62033), sodium and calcium compounds accounted for at least half the total average dustfall recorded for the year.

Among the insoluble fraction of Fort Frances dustfall, wood fines were identified as the most dominant component. At the station (62046) most influenced by fallout of this contaminant, wood fines comprised about half the total dustfall. At the Sinclair/Victoria site (62036), wood fines made up approximately a quarter of the total fallout. Sawdust was often seen in jars exposed at these locations and at stations 62030 and 62033. Trace amounts of bark char were also noted frequently in dustfall jars at all sites.

The pH of dustfall solutions (Table 6) varied from 7.3 near the mill to 4.6 at the most distant site, with an overall average of 5.4 for all stations. The existence of a gradient of pH values around the mill provides further evidence of fallout of alkaline substances in the area.

Although dustfall measurements are crude and subject to intentional or accidental contamination, they provide strong evidence that the Fort Frances kraft mill is a source of significant fallout of sawdust and other wood fines, plus chemical compounds rich in calcium, sodium and sulphate. The improvement in late 1979, caused by a reduction in sodium and sulphate (salt-cake) emissions, is expected to continue when reconstruction of the recovery furnace precipitator is completed in the spring of 1980. A recently released control order specifies that the wood fines problem must be solved by late 1983. There is no evidence that emissions from the kraft mill in International Falls have any impact on dustfall levels in Fort Frances.

Suspended Particulate Matter

Measurements of suspended particulate matter with high volume samplers have been conducted regularly in Fort Frances since late 1975. The monitoring procedure is outlined in the 1977 air quality report (2).

Concentrations of total suspended particulate matter (TSP) at the two Fort Frances monitoring stations are listed in Table 7. At station 62030, near the mill, the 24-hour Ontario objective of $120 \mu\text{g}/\text{m}^3$ (micrograms of TSP per cubic metre of air) was exceeded 11 times in 1979, the same frequency as in 1978. The annual average of $68 \mu\text{g}/\text{m}^3$ was slightly above the objective of 60 and also higher than the mean of 57 for 1978. Highest readings were obtained with south winds (downwind of the mill) and lowest values were recorded for east winds. Wood fibres were often seen on sample filters exposed at station 62030.

Most TSP concentrations at station 62032 were acceptable, with only three samples above the 24-hour air quality objective. The annual mean, $39 \mu\text{g}/\text{m}^3$, was well within provincial regulations. Particulate matter concentrations at this location were higher for east and south winds than for west or north wind.

GASEOUS POLLUTANTS

Sulphation Rate

The sulphation rate method, described in other reports (1, 2), provides a semi-quantitative estimate of average monthly levels of airborne sulphur-containing gases. The 1979 data for Fort Frances, reproduced in Table 8, reveal that the highest values, near the mill, averaged five times the level for the most distant location. The overall average sulphation rate for 1979 was a little lower than that for 1978 (0.18 mg SO_3 compared with 0.22 mg SO_3).

Total Reduced Sulphur

Total reduced sulphur (TRS) comprises a group of sulphur-containing gases which are commonly associated with emissions from kraft pulp mills. These gases are perceived as

very offensive odours if present at even very low concentrations. Higher levels of TRS may darken paint, cause vegetation injury, or cause temporary discomfort to the local population. In Fort Frances, the Ministry operates two continuous TRS analysers (Philips 9700 series) which respond to the presence of three (hydrogen sulphide, mercaptans, and dimethyl sulphide) of the four common TRS compounds.

A summary of the 1979 TRS data is contained in Table 9. At station 62030, near the kraft mill, there were 911 violations of the guideline of 27 ppb (parts per billion, hourly average). The maximum reading was 353 ppb, approximately 13 times the guideline. The distribution of the hourly readings for the year is shown in Figure 5. Despite the number of excursions above the objective, there was an improvement in 1979 over 1978. Only 11 percent of the values exceeded the guideline in 1979, compared with 14 percent in 1978. The annual average TRS concentration was also down, from 16 ppb in 1978 to 10 ppb in 1979. The wind analysis data (Table 10) show that all the high TRS concentrations originated from the Fort Frances mill (wind direction 170° - 220°). Some elevated readings were also attributed to emissions from the International Falls mill (240° - 260°), and some low TRS was recorded with wind (320° - 350°) from the mill's liquid waste treatment lagoon, 1.5 km to the northwest of the monitor.

At station 62032, more distant from the mill, TRS exceeded the 27 ppb guideline for 178 hours (2.4% of all readings) in 1979, compared with 141 (2%) in 1978. The maximum hourly concentration was 140 ppb. The annual average of 2.9 ppb showed no significant change from 1977 or 1978. Figure 6 and Table 9 show the distribution of the readings during the year. The wind analysis (Table 10) shows that highest TRS levels were associated with wind from the International Falls mill (140° - 170°), lower readings with wind from the Fort Frances mill (110° - 130°), and lowest measurable concentrations with wind from the Fort Frances mill's liquid waste treatment lagoon, 1.1 km to the north.

The high TRS levels sometimes found near the Fort Frances mill might cause discomfort to some local residents. The most sensitive individuals would include infants, the aged, and those suffering from respiratory ailments. Any effects would be temporary and would be alleviated by reduced emissions from the mill or by a change in wind direction. There is no evidence known to the Ministry which suggests that exposure to TRS near kraft pulp mills can cause long-term health effects.

As noted above, there was some indication of reduction in average TRS concentrations near the Fort Frances mill in 1979. Further improvement is expected during the next two years, as the mill complies with provisions contained in a recently issued control order.

ACKNOWLEDGEMENT

The Ministry wishes to thank staff of the Ministry of Industry and Tourism, Fort Frances, for assistance in operating the TRS monitor at station 62030.

REFERENCES

1. Ontario Ministry of the Environment. 1979. Air quality, Fort Frances. Annual Report, 1978.
2. Ontario Ministry of the Environment. 1978. Air quality, Fort Frances. Annual Report, 1977.

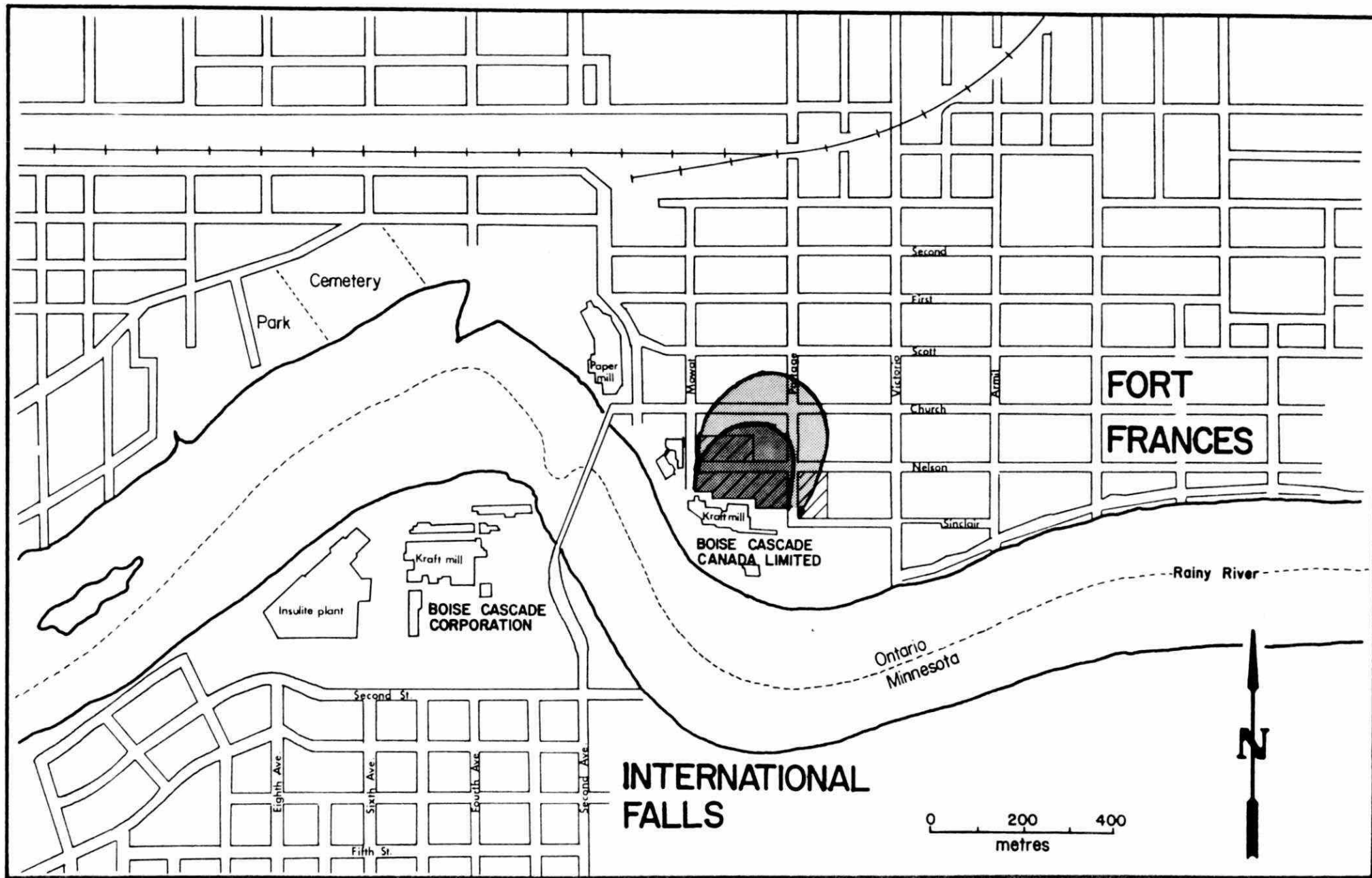


Figure 1. Zone of air pollution injury to Manitoba maple, August, 1979.

-  Buffer zone
-  Moderate to severe injury
-  Trace to light injury

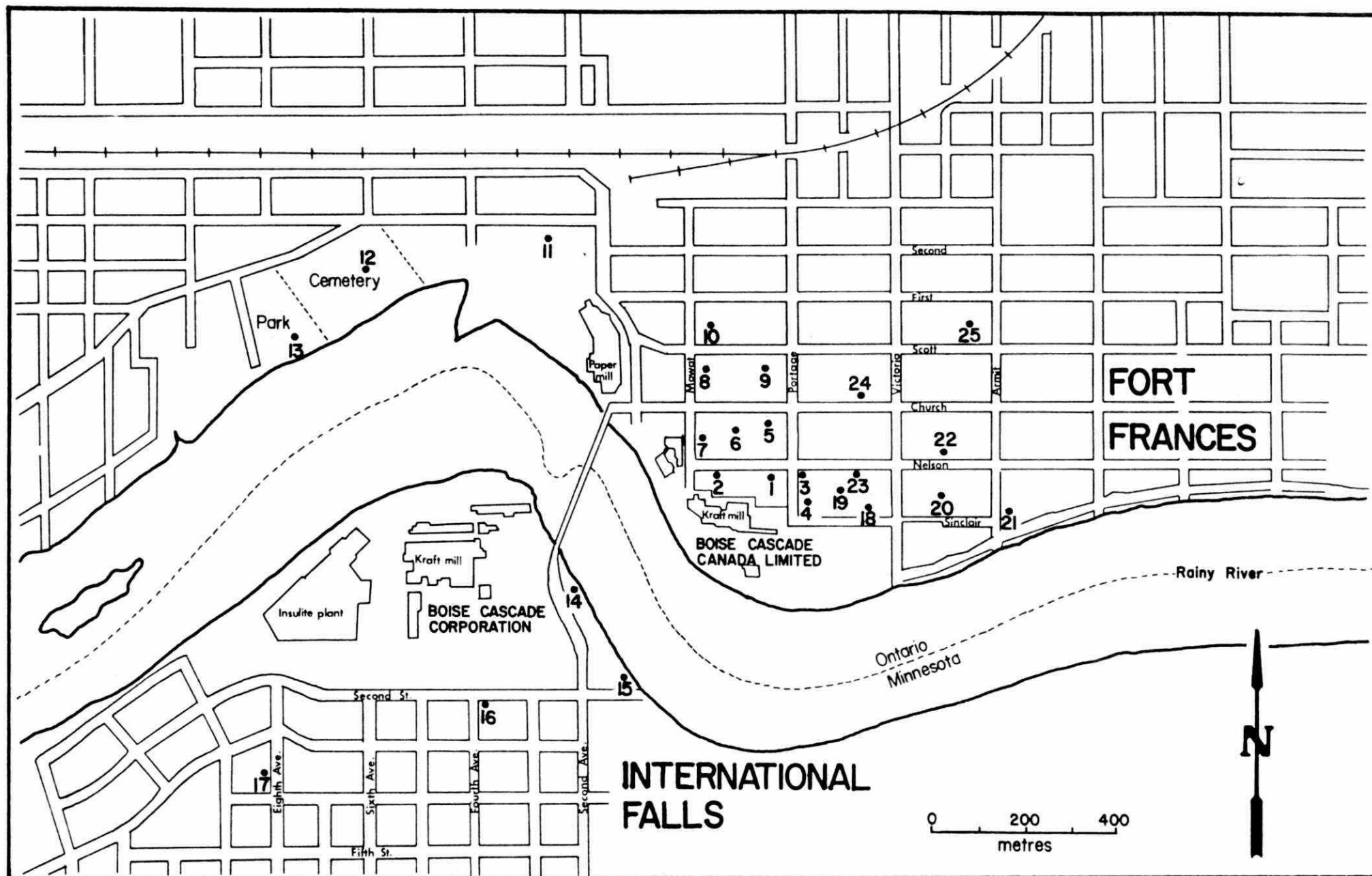


Figure 2. Manitoba maple sampling sites, 1979.

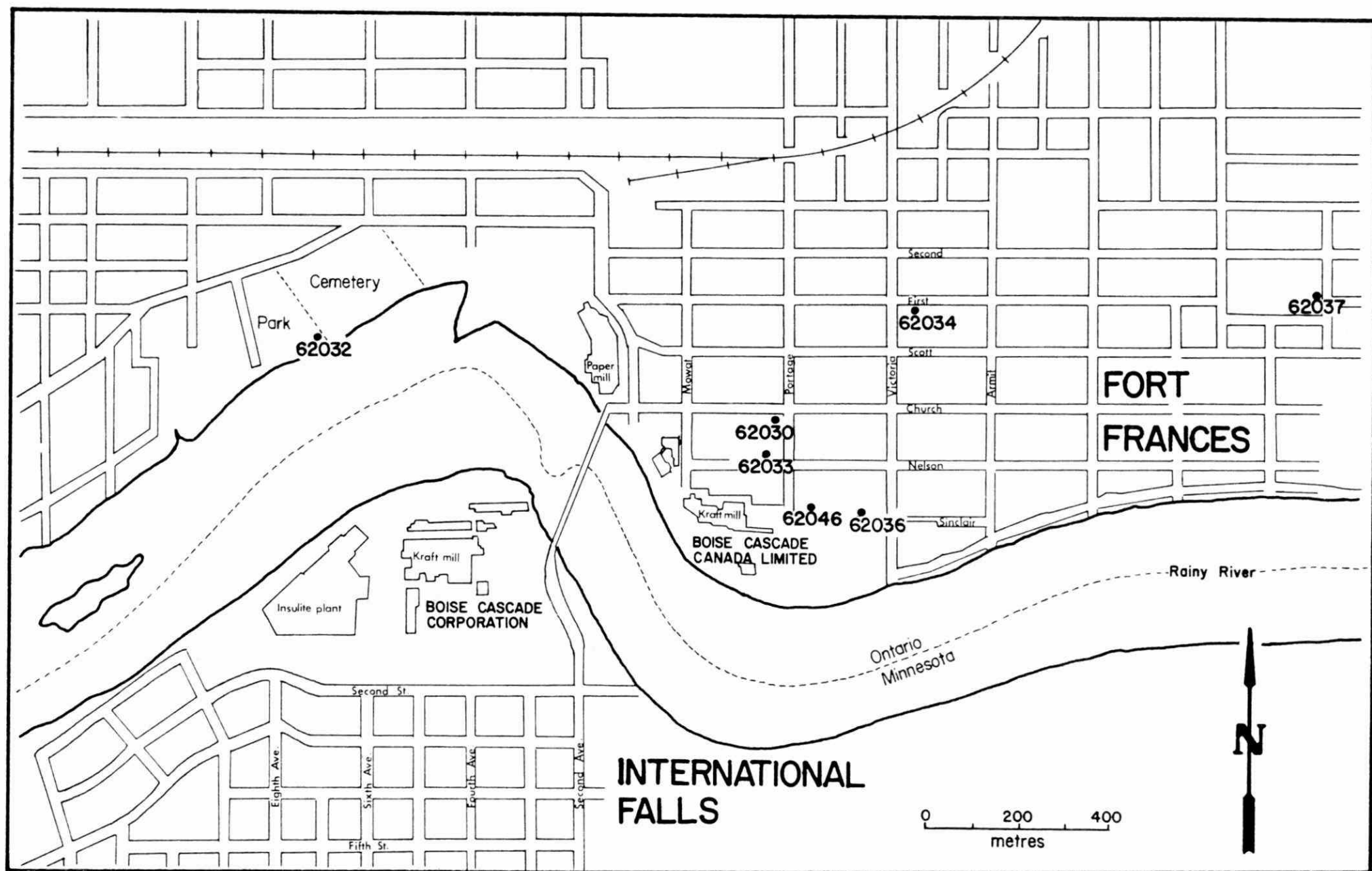


Figure 3. Air quality monitoring sites, 1979.

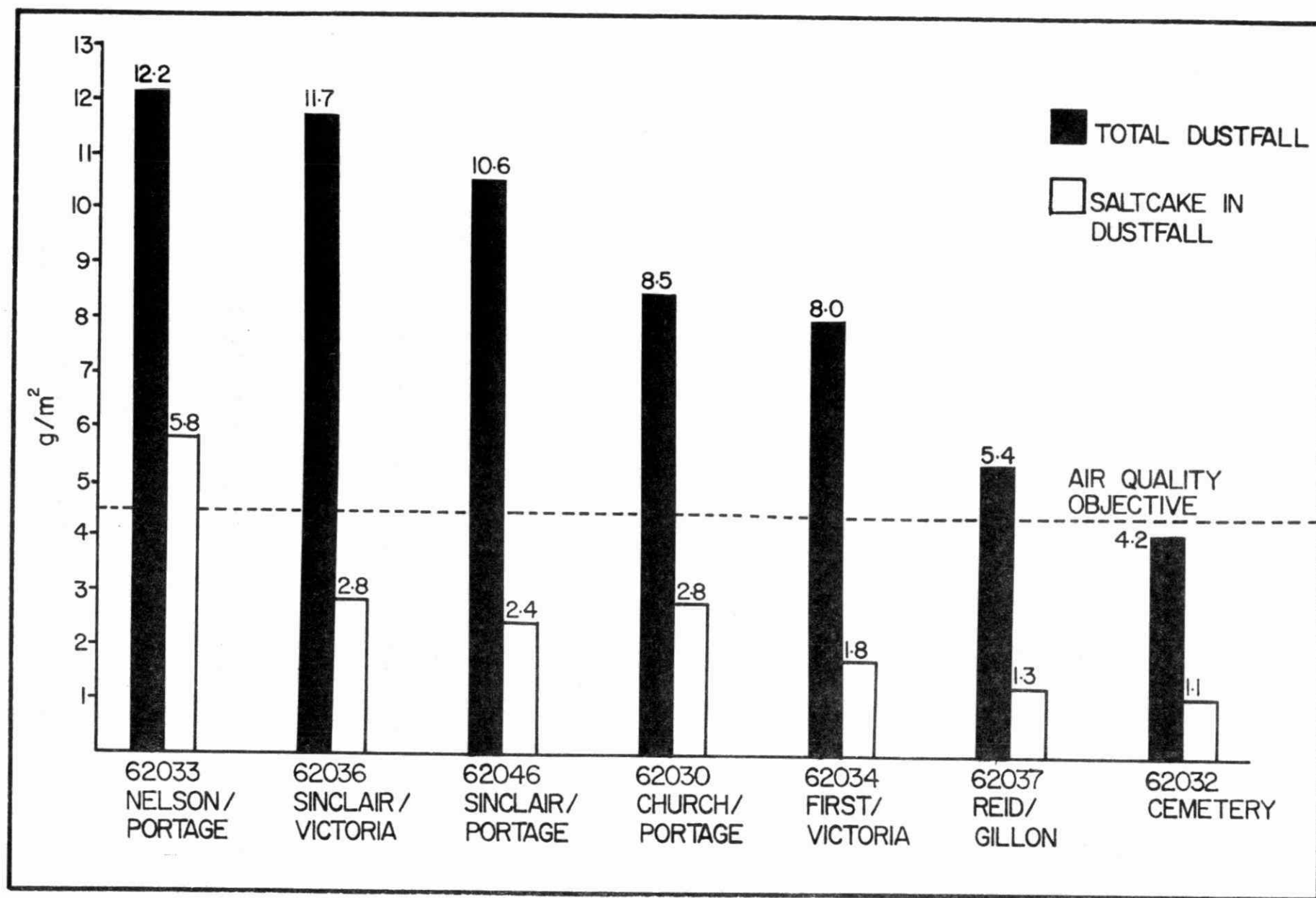


Figure 4. Annual average dustfall, Fort Frances , 1979.

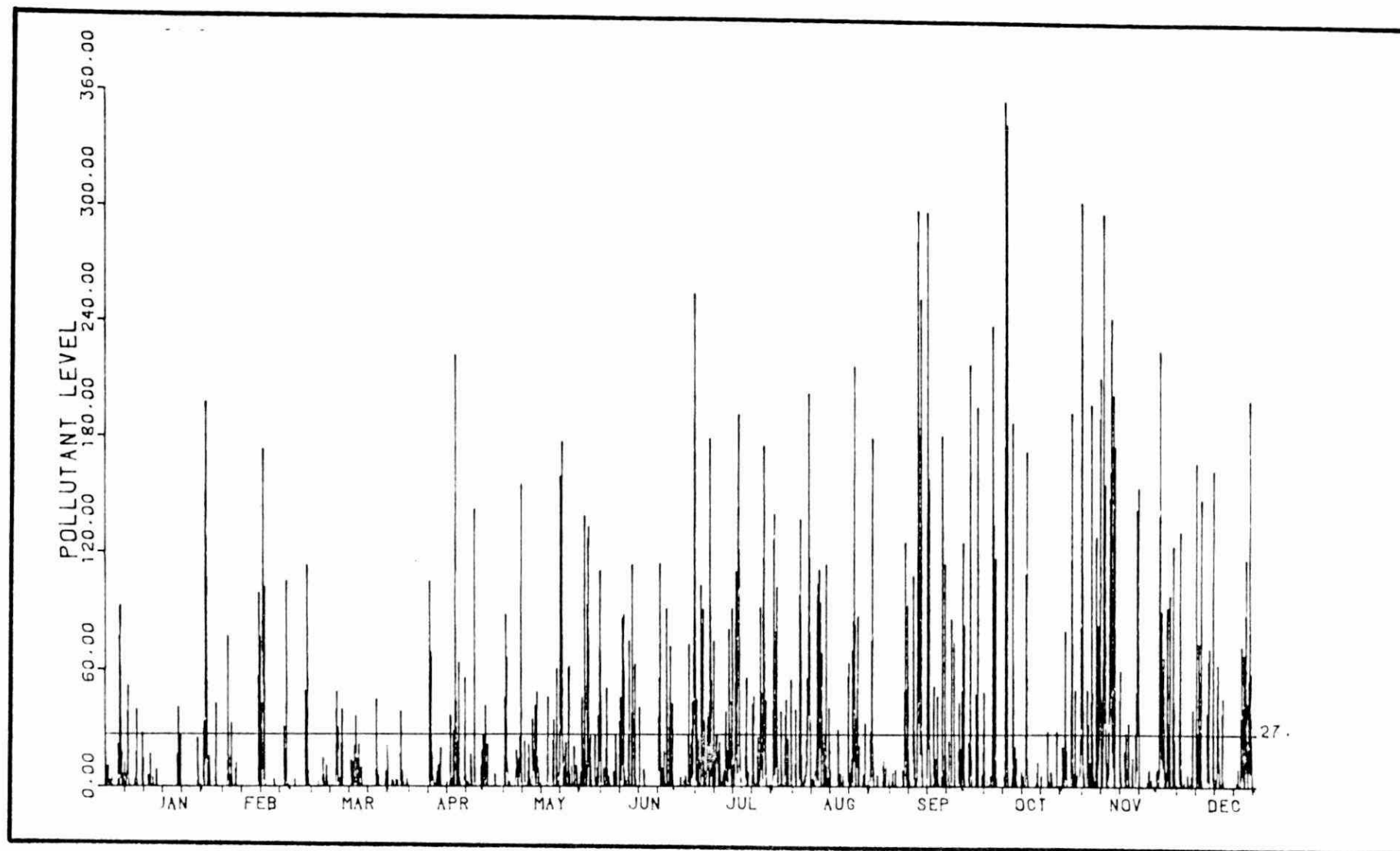


Figure 5. Hourly average TRS concentrations (parts per billion), station 62030, Fort Frances, 1979.

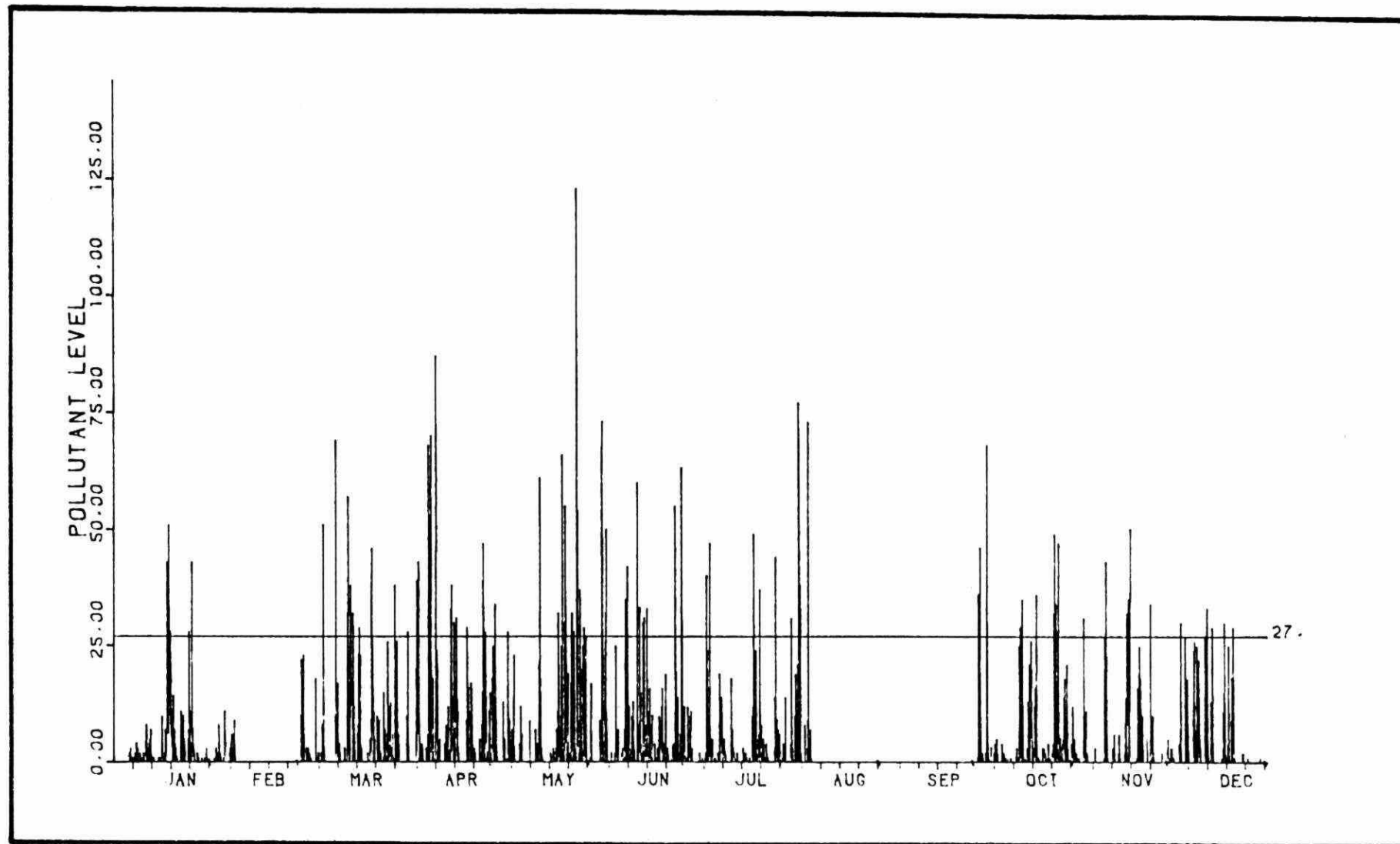


Figure 6. Hourly average TRS concentrations (parts per billion), station 62032 , Fort Frances, 1979.

TABLE 1. Average chloride and sodium concentrations in unwashed Manitoba maple foliage^a, Fort Frances-International Falls, 1975-1979.

Site (Figure 2)	Chloride (% dry weight basis)					Sodium (µg/g dry weight)				
	1975	1976	1977	1978	1979	1975	1976	1977	1978	1979
1	.26	.29	.37	.33	.93	540	<u>770^b</u>	<u>2200</u>	<u>1100</u>	<u>2900</u>
2					.77					<u>1500</u>
3					.43					<u>810</u>
4					.21					<u>530</u>
5					.25					<u>700</u>
6	.37	.16	.18	.22	.29	460	<u>1100</u>	600	400	<u>680</u>
7					.30					<u>720</u>
8					.15					<u>230</u>
9	.33	.14	.20	.19	.21	400	120	140	170	370
10	.08	.09	.07	.14	.09	320	100	150	120	270
11	.08	.10	.12	.07	.08	350	180	140	67	230
12	.07	.08	.06	.08	.12	560	130	140	53	320
13	.04	.03	.04	.02	.04	<u>1500</u>	160	100	72	290
14	.13	.12	.05	.04	.15	<u>1000</u>	140	290	53	140
15	.13	.17	.09	.11	.22	<u>310</u>	220	160	72	310
16	.05	.08	.06	.08	.14	<u>700</u>	150	150	95	260
17	.10	.07	.04	.05	.07	<u>280</u>	100	140	71	390
18	.07	.13	.06	.08	.13	250	170	180	98	240
19					.11					190
20					.10					240
21	.18	.14	.09	.12	.24	200	120	130	110	400
22					.13					330
23					.16					140
24	.13	.12	.13	.07	.13	190	150	140	43	180
25	.12	.16	.06	.07	.15	180	180	230	97	280
controls	.04	.05	.06	.05	.06	70	76	52	38	46
normal background						<600	<600	<600	<600	<600

^a values are averages for three sets of triplicate samples in 1975, and one set for other years

^b values above normal background (600 µg/g) are underlined

TABLE 2. Total dustfall ($\text{g/m}^2/30$ days), Fort Frances, 1979.

Station	Location	Distance (metres) and direction from source ^a	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
62030	Church/Portage	215 NNE	3.0	5.9	3.2	<u>10.9</u>	<u>8.8</u>	<u>14.6</u>	<u>13.7</u>	<u>16.9</u>	6.6	4.9	<u>8.7</u>	4.3	<u>8.5</u>
62032	Cemetery	990 WNW	1.0	<u>8.6</u>	3.1	5.3	5.5	6.5	4.6	6.2	2.7	2.2	3.1	1.1	4.2
62033	Nelson/Portage	135 NNE	3.8	2.8	-	<u>11.7</u>	<u>10.7</u>	<u>20.8</u>	<u>25.6</u>	<u>22.4</u>	<u>8.3</u>	<u>8.3</u>	<u>10.6</u>	<u>9.3</u>	<u>12.2</u>
62034	First/Victoria	590 NE	2.2	2.2	5.8	6.3	-	<u>11.6</u>	<u>24.7</u>	<u>14.9</u>	4.5	3.1	<u>7.3</u>	5.0	<u>8.0</u>
62036	Sinclair/Victoria	295 E	6.6	3.6	<u>8.4</u>	<u>11.4</u>	<u>14.9</u>	-	<u>26.0</u>	<u>22.2</u>	<u>9.7</u>	<u>9.3</u>	<u>8.7</u>	<u>8.4</u>	<u>11.7</u>
62037	Reid/Gillon	1385 E	0.5	0.9	3.4	<u>13.0</u>	<u>12.2</u>	<u>8.3</u>	5.6	6.6	3.3	4.3	2.0	4.5	<u>5.4</u>
62046	Sinclair/Portage	150 E	6.9	3.8	6.8	<u>9.8</u>	<u>11.9</u>	<u>17.4</u>	<u>25.2</u>	<u>17.9</u>	<u>9.8</u>	5.4	<u>8.3</u>	<u>11.2</u>	<u>10.6</u>

^asource arbitrarily designated as Boise Cascade Canada Limited kraft mill recovery furnace stack

^bunderlined values exceed maximum acceptable levels of 7.0 (monthly) or 4.6 (annual average)

TABLE 3. Soluble calcium ($\text{g/m}^2/30$ days) in dustfall, Fort Frances, 1979.

Station	Location	Distance (metres) and direction from source ^a	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
62030	Church/Portage	215 NNE	0.2	0.7	-	0.6	0.6	0.8	-	-	0.2	0.4	0.4	0.3	0.5
62032	Cemetery	990 WNW	0.1	0.2	0.2	0.3	0.2	0.3	0.1	0.2	0.1	0.5	0.1	<0.1	0.2
62033	Nelson/Portage	135 NNE	0.5	0.9	1.4	0.3	1.0	0.9	0.8	1.1	0.7	1.0	0.4	0.4	0.8
62034	First/Victoria	590 NE	0.2	0.1	0.1	0.3	-	0.4	0.2	0.4	0.2	0.2	0.2	0.2	0.2
62036	Sinclair/Victoria	295 E	0.3	0.3	0.8	0.7	1.0	0.6	0.4	0.5	0.3	0.9	0.3	0.3	0.5
62037	Reid/Gillon	1385 E	0.1	0.1	0.1	0.4	0.4	0.2	0.1	0.1	0.1	0.3	<0.1	<0.1	0.2
62046	Sinclair/Portage	150 E	0.7	0.2	0.7	0.8	1.1	0.8	0.6	1.1	0.5	1.0	0.3	0.4	0.7

^asource arbitrarily designated as Boise Cascade Canada Limited kraft mill recovery furnace stack

TABLE 4. Soluble sodium ($\text{g/m}^2/30$ days) in dustfall, Fort Frances, 1979.

Station	Location	Distance (metres) and direction from source ^a	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
62030	Church/Portage	215 NNE	0.2	0.4	-	0.3	0.3	1.2	-	-	0.3	1.0	0.7	0.6	0.6
62032	Cemetery	990 WNW	0.1	0.3	0.2	0.3	0.5	0.3	0.5	0.9	<0.1	0.4	<0.1	0.1	0.3
62033	Nelson/Portage	135 NNE	0.3	0.9	0.9	0.8	0.1	2.1	4.8	4.4	0.8	1.4	0.8	1.8	1.6
62034	First/Victoria	590 NE	0.1	0.2	0.3	0.2	-	0.3	0.9	1.6	0.2	0.5	0.5	1.0	0.5
62036	Sinclair/Victoria	295 E	0.3	0.2	0.6	0.4	0.4	0.7	2.1	1.2	0.2	0.9	0.5	0.6	0.7
62037	Reid/Gillon	1385 E	0.1	0.1	0.1	0.2	0.6	0.1	1.0	0.8	<0.1	0.3	0.3	0.8	0.4
62046	Sinclair/Portage	150 E	0.3	0.2	0.3	0.3	0.1	0.8	2.0	1.4	0.3	0.6	0.3	0.8	0.6

^asource arbitrarily designated as Boise Cascade Canada Limited kraft mill recovery furnace stack

TABLE 5. Soluble sulphate ($\text{g/m}^2/30$ days) in dustfall, Fort Frances, 1979.

Station	Location	Distance (metres) and direction from source ^a	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
62030	Church/Portage	215 NNE	0.4	1.1	-	0.9	1.2	2.5	-	-	0.5	0.8	0.9	1.0	1.0
62032	Cemetery	990 WNW	0.3	0.7	0.7	1.1	0.5	0.9	1.0	1.6	0.2	0.4	0.2	0.3	0.6
62033	Nelson/Portage	135 NNE	0.8	2.3	2.5	2.4	3.2	5.4	<u>8.5</u> ^b	5.4	1.6	2.0	1.6	3.3	3.2
62034	First/Victoria	590 NE	0.3	0.5	0.7	0.8	-	0.8	1.6	2.8	0.3	0.5	0.9	1.6	1.0
62036	Sinclair/Victoria	295 E	0.7	0.7	2.1	1.7	1.9	2.0	4.0	2.0	0.4	1.5	1.0	1.1	1.6
62037	Reid/Gillon	1385 E	0.2	0.2	0.4	0.9	0.8	0.7	1.9	1.5	0.3	0.6	0.2	1.2	0.7
62046	Sinclair/Portage	150 E	0.9	0.6	0.9	1.0	1.5	2.5	4.0	2.4	0.5	0.8	0.7	1.4	1.4

^asource arbitrarily designated as Boise Cascade Canada Limited kraft mill recovery furnace stack

^bunderlined values exceed maximum monthly level of $7 \text{ g/m}^2/30$ days

TABLE 6. pH in solution of soluble dustfall, Fort Frances, 1979.

Station	Location	Distance (metres) and direction from source ^a	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
62030	Church/Portage	215 NNE	7.2	7.4	7.6	7.0	7.4	7.6	7.8	7.5	-	6.7	-	6.7	7.1
62032	Cemetery	990 WNW	6.8	6.3	7.2	6.7	7.4	7.2	7.8	7.2	-	5.8	7.2	6.3	6.5
62033	Nelson/Portage	135 NNE	7.8	7.7	7.1	7.2	7.2	8.7	7.9	7.7	-	6.7	-	7.8	7.3
62034	First/Victoria	590 NE	7.0	6.6	7.3	7.1	-	7.3	7.7	7.6	-	6.2	7.2	7.8	6.9
62036	Sinclair/Victoria	295 E	7.0	6.5	6.8	6.7	7.2	7.2	8.0	7.3	-	6.5	7.0	7.5	6.9
62037	Reid/Gillon	1385 E	6.0	3.6	-	6.4	7.2	7.4	7.6	6.9	-	5.9	6.6	8.8	4.6
62046	Sinclair/Portage	150 E	7.7	6.7	7.9	7.5	7.6	7.5	8.4	7.7	-	6.8	-	8.0	7.3

^asource arbitrarily designated as Boise Cascade Canada Limited kraft mill recovery furnace stack

TABLE 7. Total suspended particulate matter ($\mu\text{g}/\text{m}^3$), Fort Frances, 1979.

Date	Stations		Wind ^a	Date	Stations		Wind ^a
	62030	62032			62030	62032	
Jan 3	31	11	270	Jul 2	64	107	120
9	2	13	290	8	85	<u>134</u>	160
15	35	21	250	14	<u>141</u>	<u>86</u>	280
21	27	27	300	20	<u>292</u>	83	210
27	14	14	350	26	<u>62</u>	58	40
Feb 2	40	19	260	Aug 1	<u>223</u>	59	200
8	-	21	360	7	<u>84</u>	<u>128</u>	290
14	36	35	70	13	66	<u>54</u>	300
20	101	74	340	19	-	84	20
26	-	60	170	25	89	53	300
				31	54	<u>144</u>	130
Mar 4	31	18	360	Sep 6	49	39	310
10	53	19	290	12	86	37	240
16	<u>177</u> ^b	64	170	18	77	33	330
22	<u>98</u>	46	250	24	<u>172</u>	54	270
28	55	33	20	30	<u>85</u>	43	220
Apr 3	78	63	300	Oct 6	42	20	310
9	111	53	10	12	57	-	340
15	67	58	280	18	63	-	150
21	<u>189</u>	29	160	24	-	35	360
27	<u>139</u>	58	360	30	31	30	80
May 3	69	-	300	Nov 5	103	28	340
9	56	25	10	11	69	41	170
15	74	55	280	17	<u>159</u>	61	180
21	-	-	160	23	<u>243</u>	-	10
27	-	-	360	29	<u>29</u>	13	310
Jun 2	77	26	250	Dec 5	49	16	310
8	65	45	300	11	28	19	340
14	<u>294</u>	83	190	17	88	28	180
20	<u>54</u>	74	90	23	-	13	50
26	<u>175</u>	65	280	29	44	24	240

^a prevailing wind direction, degrees, recorded 6.4 m above ground level at International Falls airport, Minnesota

^b underlined values exceed maximum acceptable level of $120 \mu\text{g}/\text{m}^3$ (24-hour average)

TABLE 8. Sulphation rate ($\text{mg SO}_2/100 \text{ cm}^2/\text{day}$), Fort Frances, 1979.

Station	Location	Distance (metres) and direction from source ^a	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
62030	Church/Portage	215 NNE	.18	.15	.10	.12	.30	.12	.42	.17	.29	.18	-	.14	.20
62032	Cemetery	990 WNW	.12	.21	.20	.21	.12	.14	.05	.12	.12	.11	.06	.09	.13
62033	Nelson/Portage	135 NNE	.21	.22	.21	.22	.54	.23	.68	.51	.48	.48	.56	.42	.40
62034	First/Victoria	590 NE	.12	.04	.21	.04	.29	.03	.21	.12	.09	.08	.15	.16	.13
62036	Sinclair/Victoria	295 E	.14	.09	.10	.06	.17	.27	.11	.07	.17	.12	.15	.16	.13
62037	Reid/Gillon	1385 E	.12	.08	.09	.03	.15	.04	.12	.04	.06	.08	.11	.12	.09
62046	Sinclair/Portage	150 E	.18	.13	.14	.08	.40	.16	.41	.21	.38	.23	-	.22	.23

^asource arbitrarily designated as Boise Cascade Canada Limited kraft mill recovery furnace stack

TABLE 9. Distribution of readings of total reduced sulphur (in ppb, hourly average), Fort Frances, 1979.

Month	Days of data	Number of readings for concentrations of:						Maximum value:	
		0-10	11-27	28-50	51-100	101-300	>300	Hour	Day
Station 62030									
Jan	25	534	40	8	7	0	0	93	27
Feb	25	498	44	22	14	16	0	197	55
Mar	28	632	43	15	3	2	0	113	21
Apr	30	657	28	20	8	4	0	222	30
May	31	620	70	26	14	5	0	177	56
Jun	25	480	62	45	31	7	0	139	39
Jul	31	453	143	70	43	24	0	254	67
Aug	29	507	92	57	47	14	0	216	59
Sep	30	532	65	45	31	26	0	297	98
Oct	31	640	44	19	13	22	2	353	56
Nov	29	487	72	60	39	36	1	301	87
Dec	30	525	83	61	43	11	0	224	44
YEAR	344	6565	776	448	293	167	3	353	98
Station 62032									
Jan	30	689	23	8	1	0	0	51	18
Feb	5	163	1	0	0	0	0	11	2
Mar	31	652	48	19	4	0	0	69	20
Apr	30	626	54	27	5	0	0	87	20
May	31	631	71	14	7	2	0	123	18
Jun	28	610	32	18	5	0	0	73	12
Jul	28	639	23	5	0	0	0	49	7
Aug	13	273	12	5	5	0	0	77	21
Sep	24	523	29	12	6	1	0	140	19
Oct	31	685	38	14	2	0	0	68	11
Nov	24	543	33	12	0	0	0	50	14
Dec	31	672	52	6	0	0	0	33	8
YEAR	306	6706	416	140	35	3	0	140	21

TABLE 10. Directional distribution of hourly readings of total reduced sulphur (TRS) in 1978 and 1979, Fort Frances.

Wind direction ^a	Station 62030				Station 62032			
	Wind frequency (%) ^b		TRS (ppb)		Wind frequency (%) ^b		TRS (ppb)	
	1978	1979	1978	1979	1978	1979	1978	1979
10	1.6	2.6	1	0	1.7	2.7	2	4
20	1.5	2.3	1	1	1.6	2.3	1	3
30	1.0	1.4	0	0	1.2	1.4	1	1
40	1.4	1.8	1	0	1.4	1.8	1	2
50	1.5	1.6	1	2	1.5	1.8	0	4
60	1.6	1.8	1	1	1.6	1.8	1	1
70	2.1	1.8	1	0	1.9	1.7	1	1
80	2.2	1.3	1	0	1.8	1.5	1	2
90	1.9	1.3	1	1	1.9	1.4	1	3
100	1.4	1.5	1	1	1.3	1.4	6	5
110	1.2	1.9	2	0	1.2	1.9	8	9
120	3.9	3.1	1	1	4.0	3.0	11	9
130	3.4	3.4	2	1	3.6	3.5	8	9
140	2.2	3.0	5	2	2.2	3.1	8	11
150	2.5	2.8	10	3	2.6	2.6	8	12
160	3.3	2.7	17	6	3.2	2.7	9	12
170	3.0	2.9	28	18	3.0	2.8	5	6
180	4.8	3.6	42	33	4.5	3.3	2	2
190	3.1	2.6	55	43	3.3	2.4	1	1
200	2.7	2.3	88	55	2.6	2.2	1	1
210	2.1	2.0	84	60	3.2	2.1	1	1
220	1.8	1.9	72	47	1.8	2.0	1	0
230	2.2	2.1	48	29	2.2	2.2	1	0
240	2.9	3.5	31	20	2.9	3.4	0	0
250	2.9	2.9	19	13	3.2	2.9	0	0
260	3.1	2.9	15	8	3.3	3.0	0	0
270	4.1	3.3	9	3	3.9	3.5	0	0
280	2.3	3.1	6	2	2.1	3.2	0	0
290	4.9	3.8	3	1	4.4	4.0	0	0
300	8.5	5.1	2	1	8.0	5.5	0	0
310	3.3	3.6	3	1	3.3	3.6	1	0
320	2.6	3.0	3	2	2.7	3.0	1	0
330	2.2	2.9	4	4	2.2	2.7	1	0
340	2.2	2.8	3	4	2.2	2.7	1	1
350	1.5	2.1	2	2	1.5	2.1	2	1
360	1.5	3.2	1	1	1.5	3.3	2	3
Calm	5.5	5.8	17	16	6.0	5.5	4	3

^adegrees, 6.4 m above ground at International Falls airport, Minnesota^bduring periods when TRS monitors were operating

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